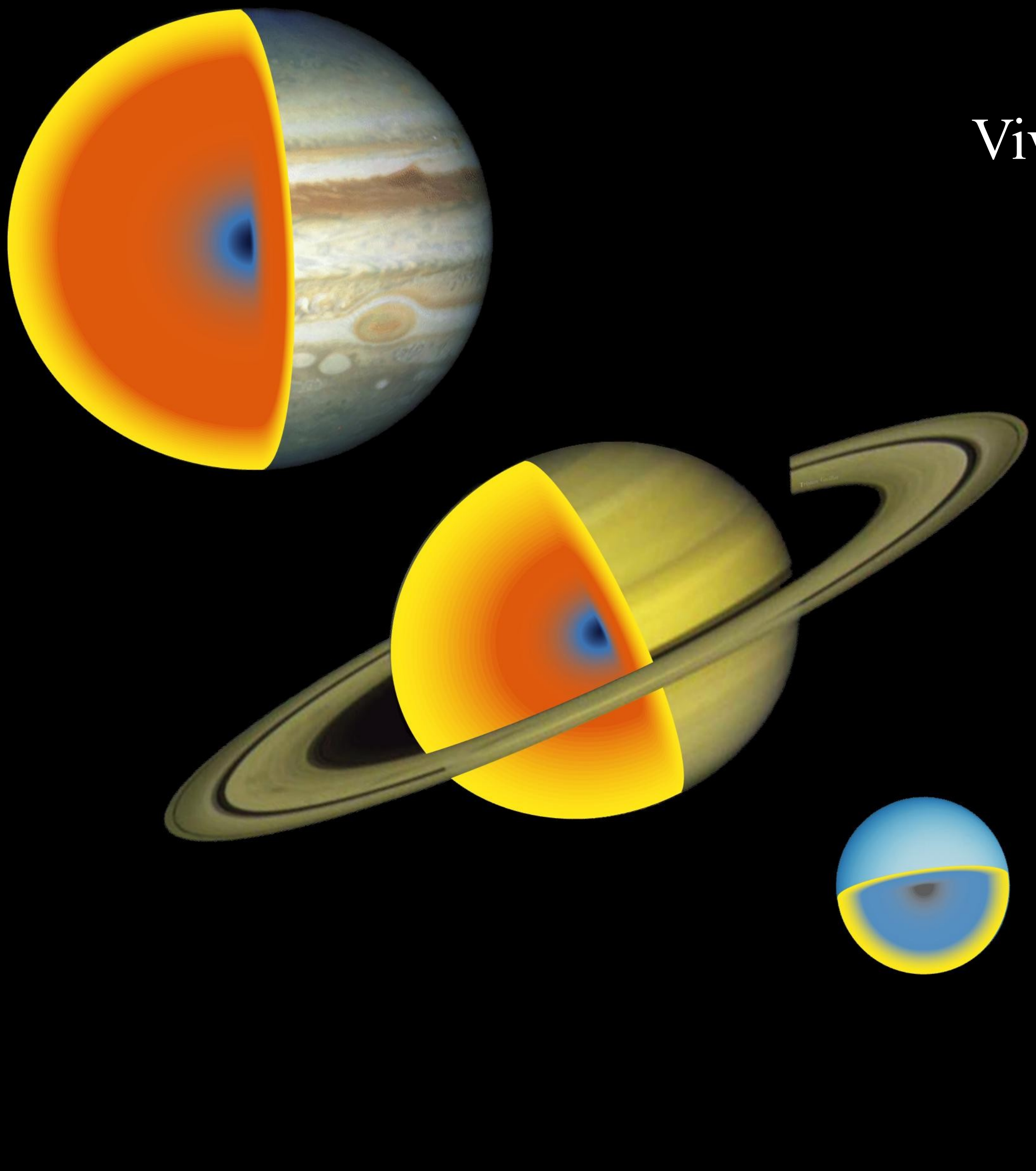
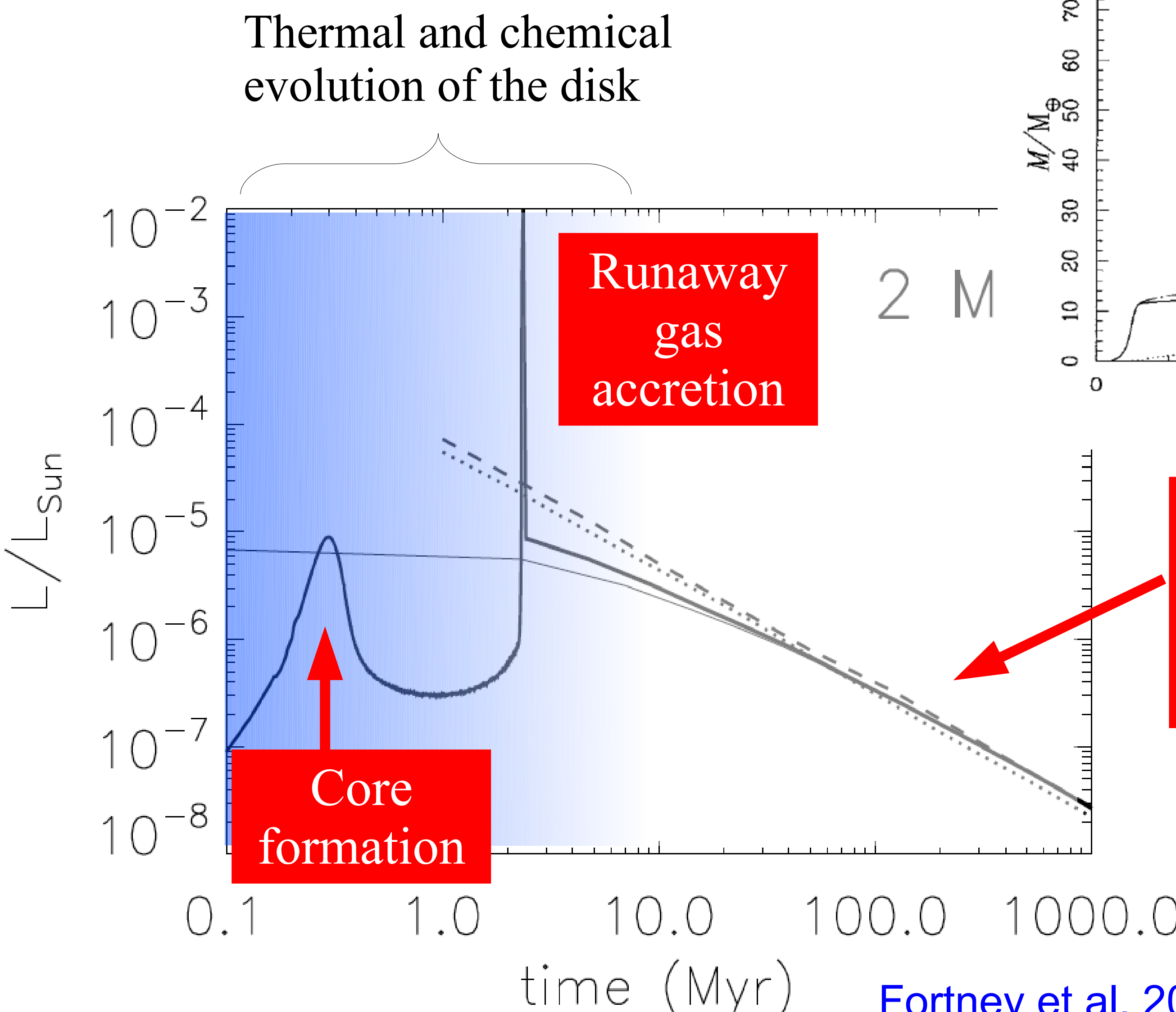
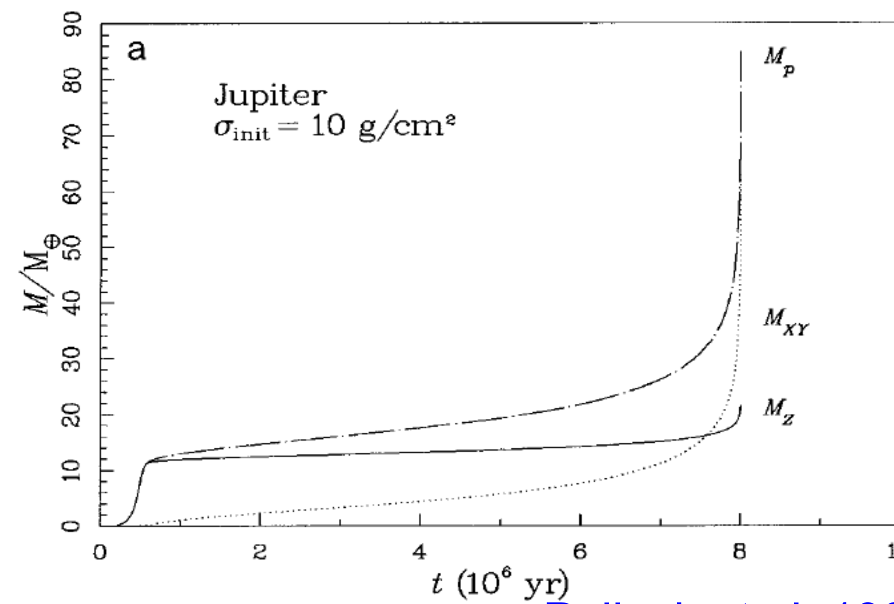
Planetary probe into giant planets what will we learn ?

Vivien Parmentier & Tristan Guillot
Observatoire de la côte d'azur
Nice, France



The life of a giant planet

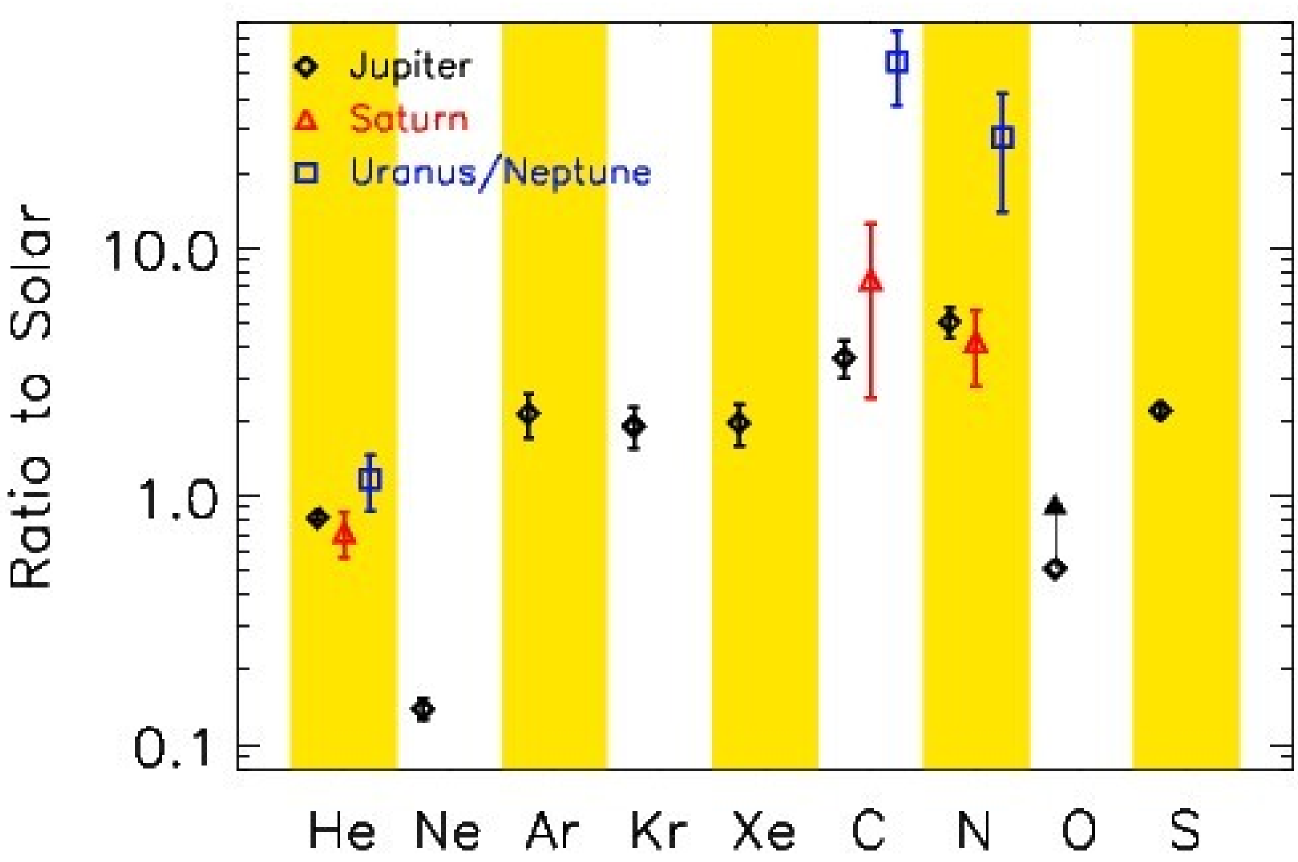




Pollack et al. 1996

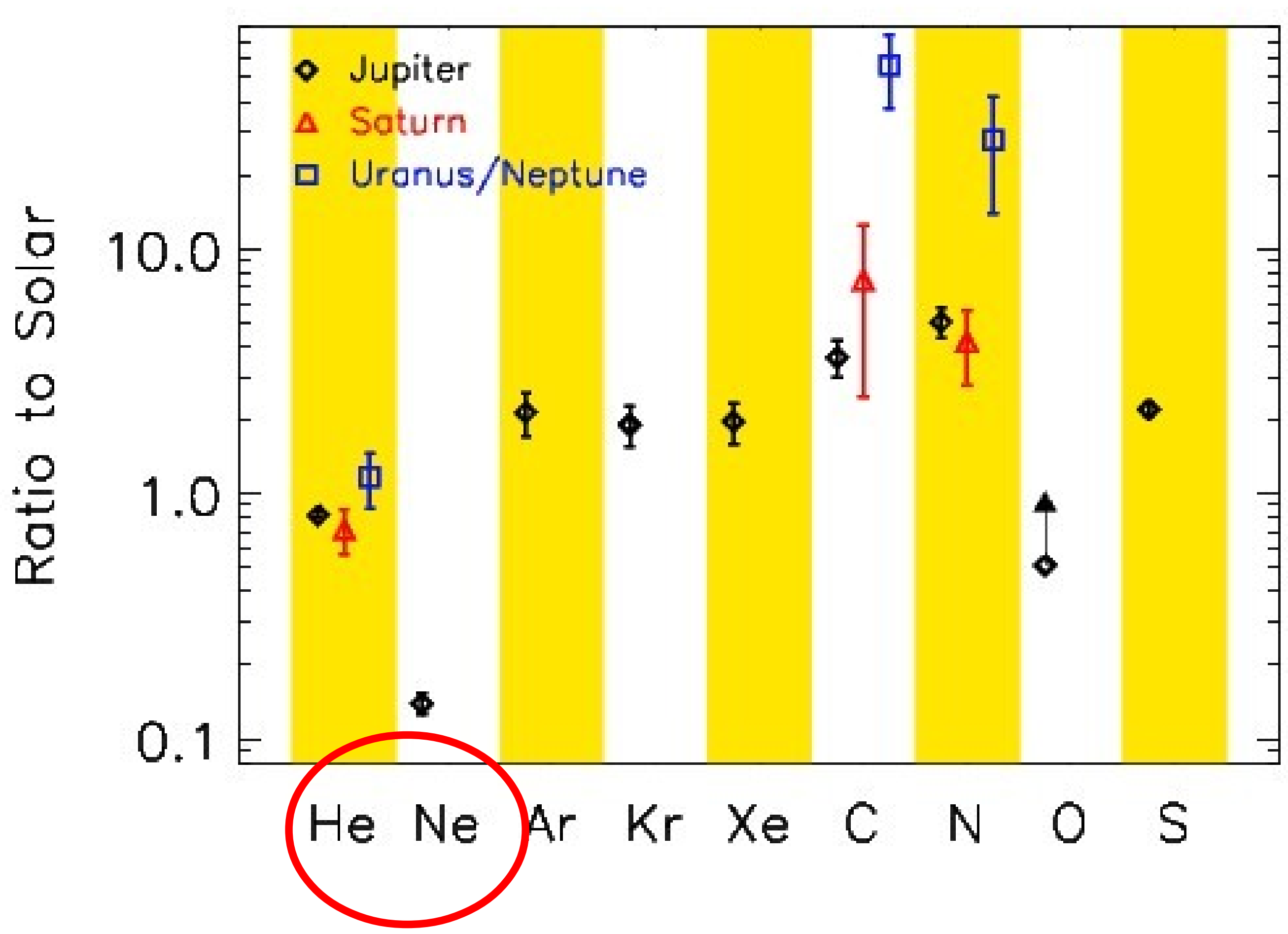
Fortney et al. 2005

Known elemental abundances in gas giants



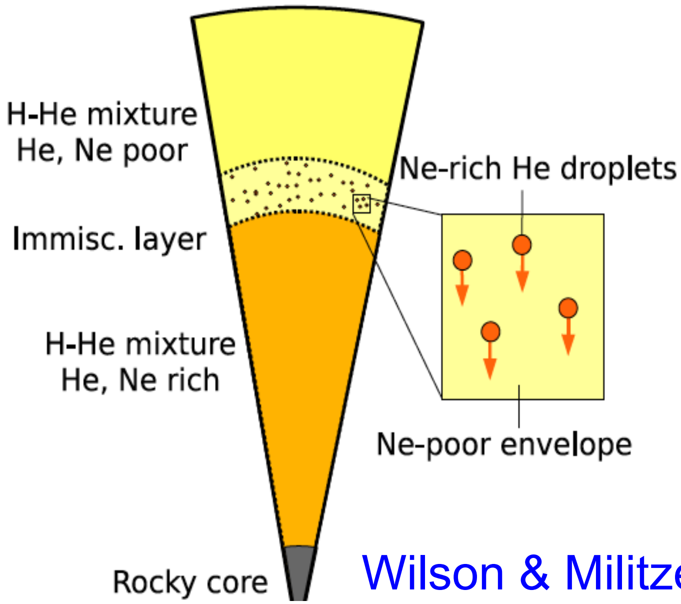
See Atreya et al. 2003, Gautier et al. 1995
Solar reference: Grevesse & Sauval 2002

Helium and Neon as a test for high pressure equation of state

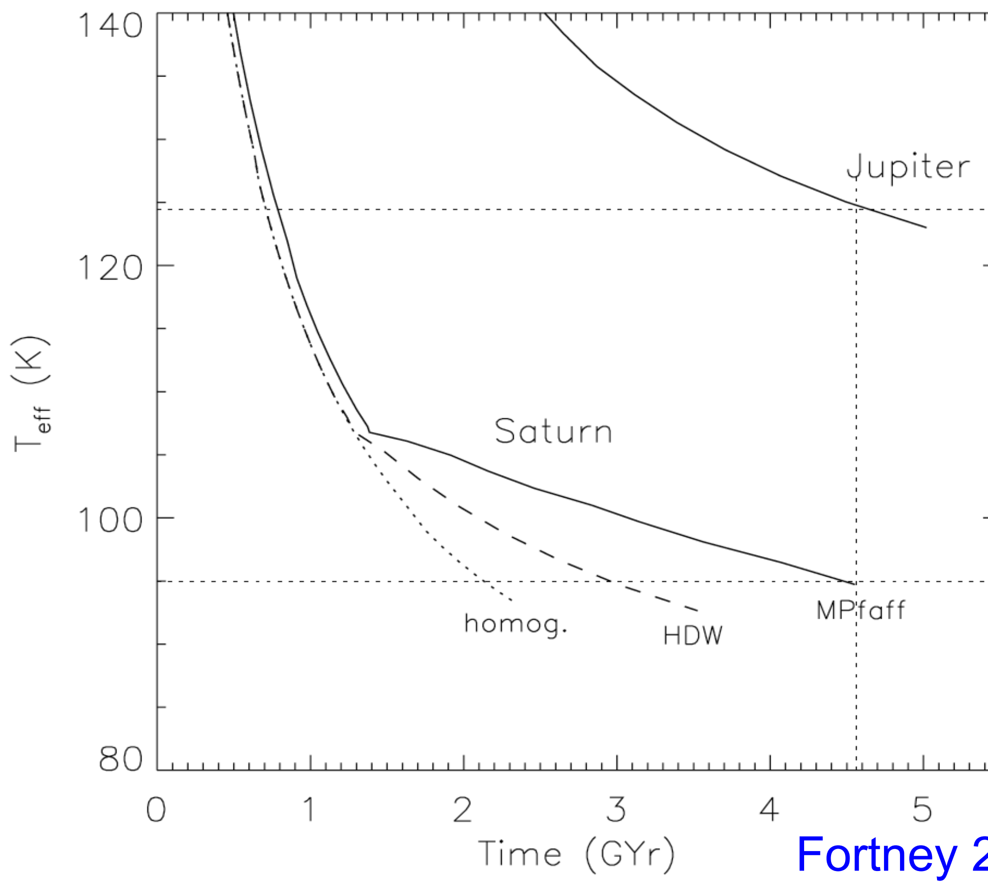


See Atreya et al. 2003, Gautier et al. 1995
Solar reference: Grevesse & Sauval 2002

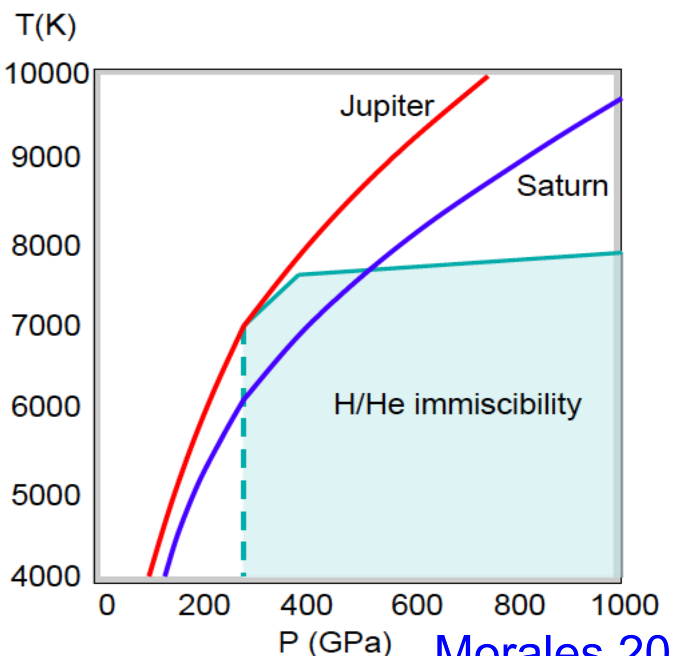
Helium and Neon as a test for high pressure equation of state



Wilson & Militzer 2010



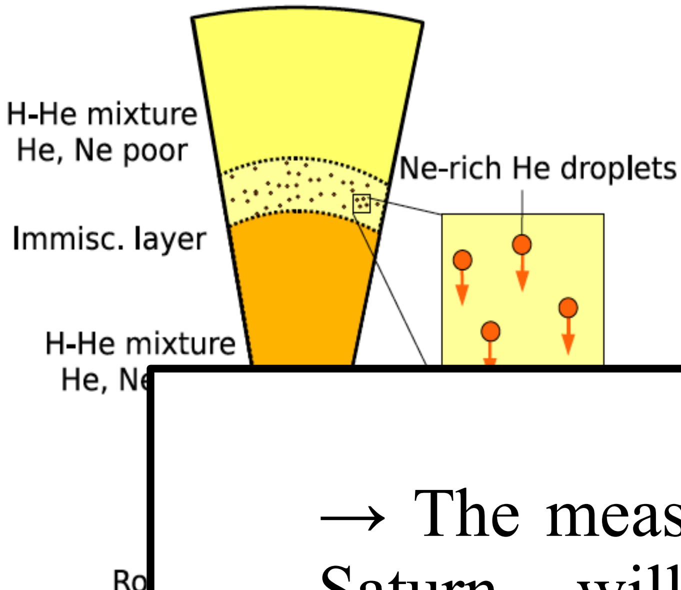
Fortney 2004

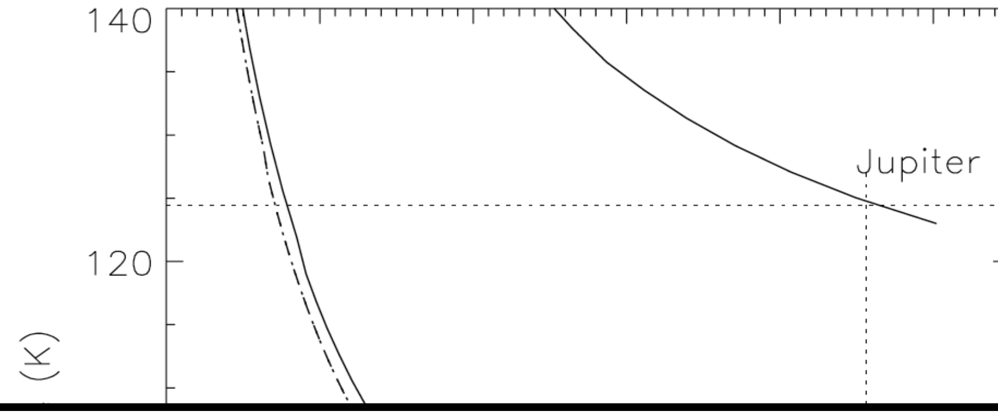


Morales 2009

- Ab-inito equation of state predicts the formation of helium droplets enriched in neon.
- Neon and helium depletion in Jupiter confirm this behavior.
- The actual high luminosity of Saturn could be explained by this helium demixing.

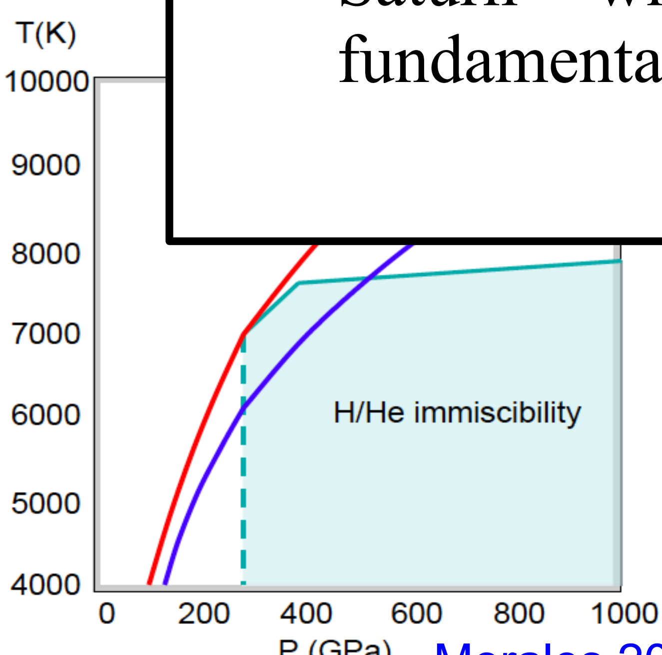
Helium and Neon as a test for high pressure equation of state





→ The measurement of He and Ne abundances in Saturn will enhance our understanding of fundamental physics and Saturn evolution.

04



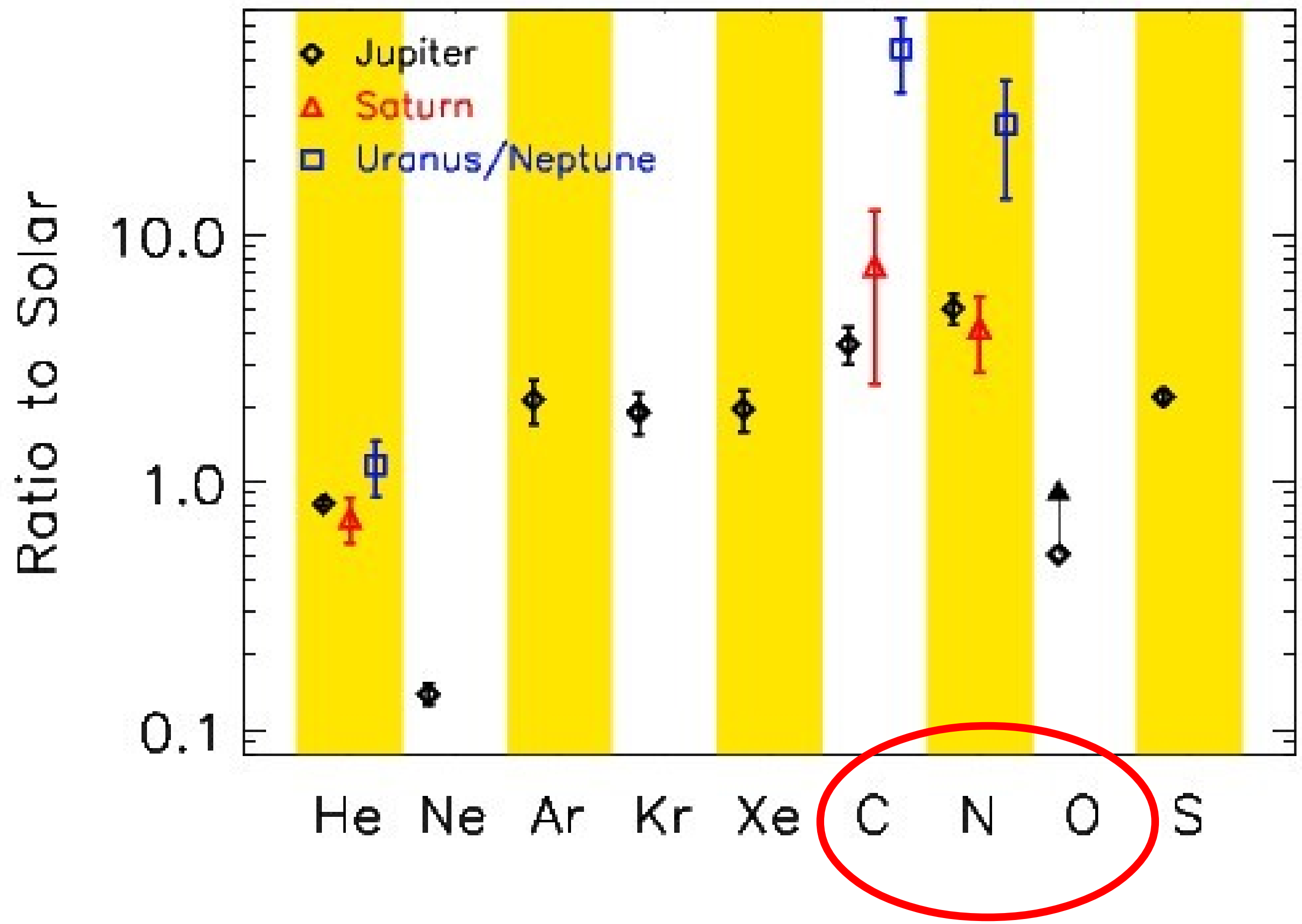
Morales 2009

Ab-inito equation of state predicts the formation of helium droplets enriched in neon.

Neon and helium depletion in Jupiter confirm this behavior.

The actual high luminosity of Saturn could be explained by this helium demixing.

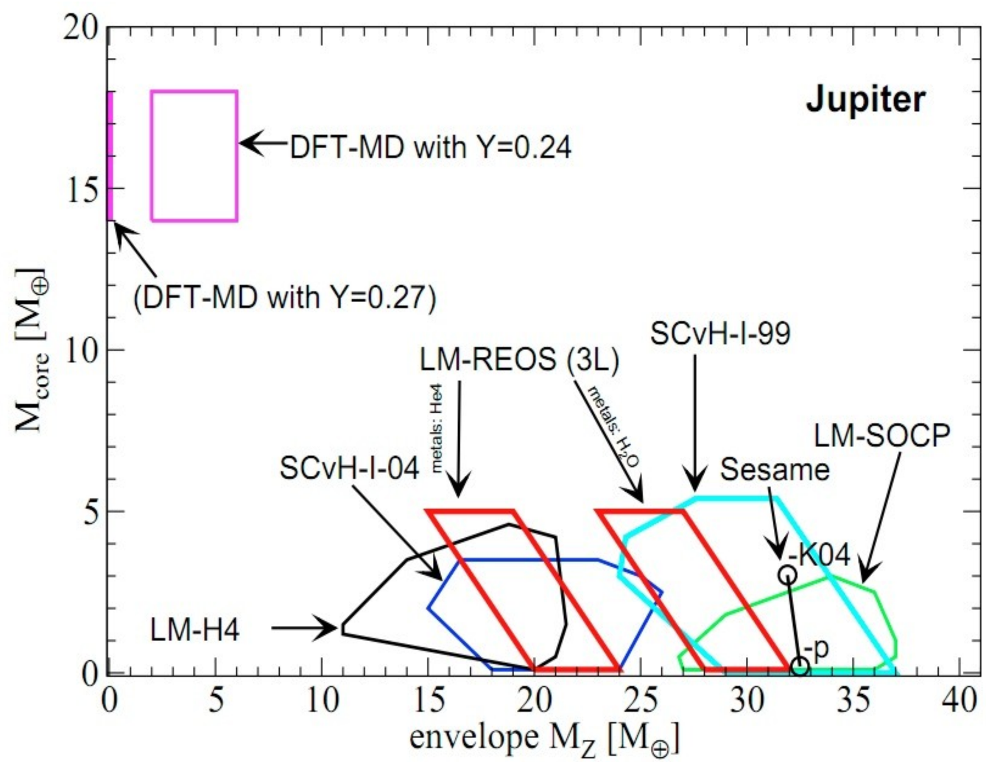
C,N,O as a proxy for the heavy elements contents of the envelope



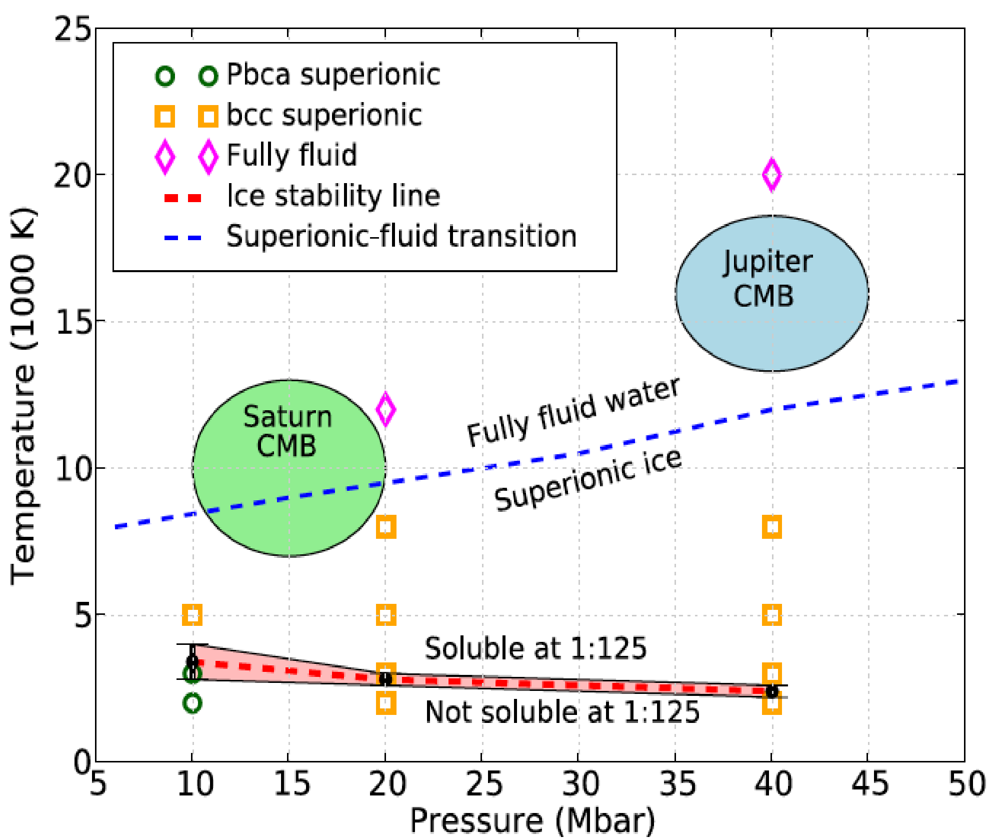
See Atreya et al. 2003, Gautier et al. 1995
Solar reference: Grevesse & Sauval 2002

C,N,O as a proxy for the heavy elements contents of the envelope

- Heavy element content influence the evolution of the planet
- Core erosion & inhomogeneous interior might influence the measured enrichment

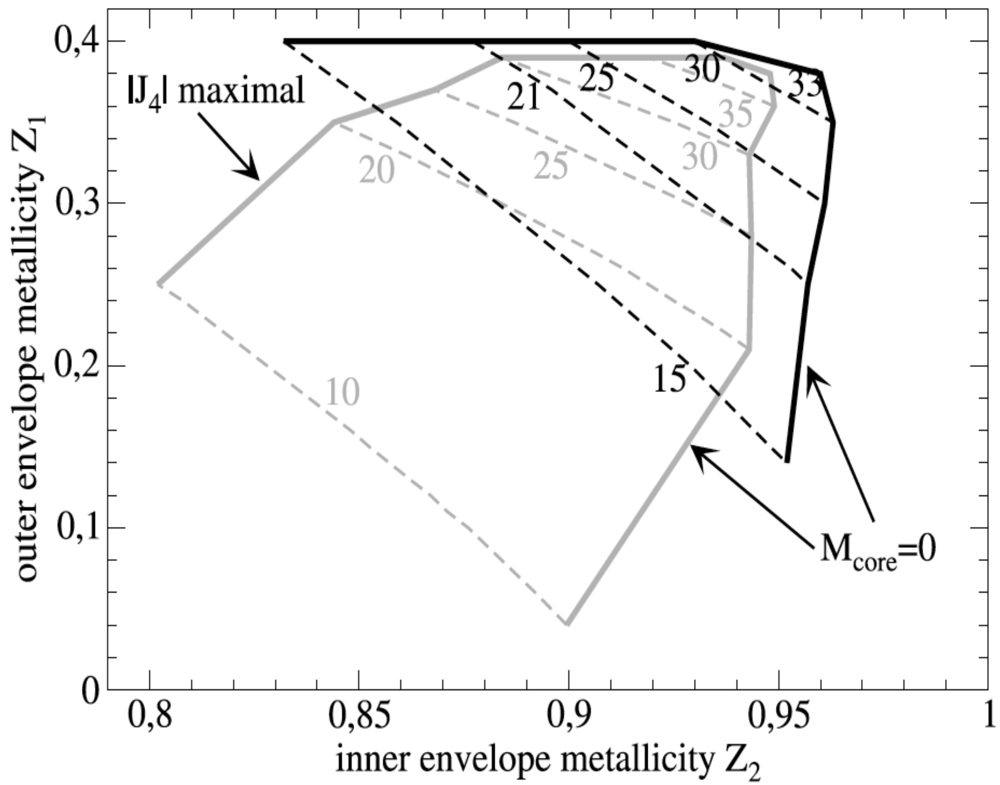


Fortney & Nettelmann 2010

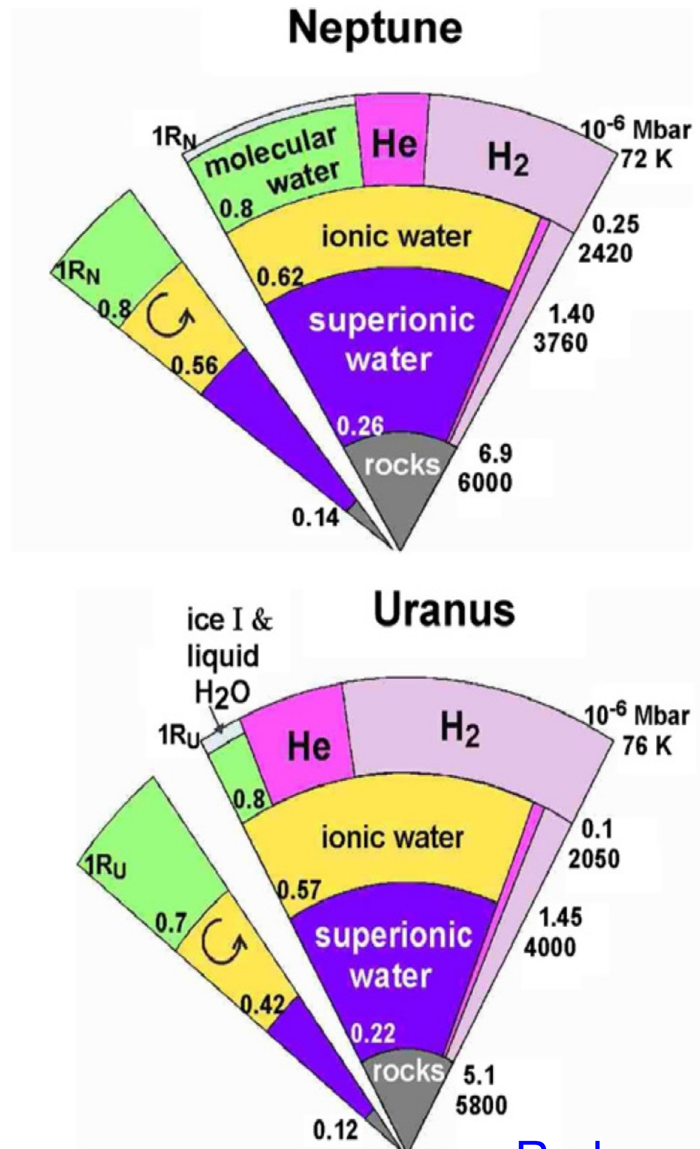


Wilson & Militzer 2012

C,N,O as a proxy for the heavy elements contents of the envelope



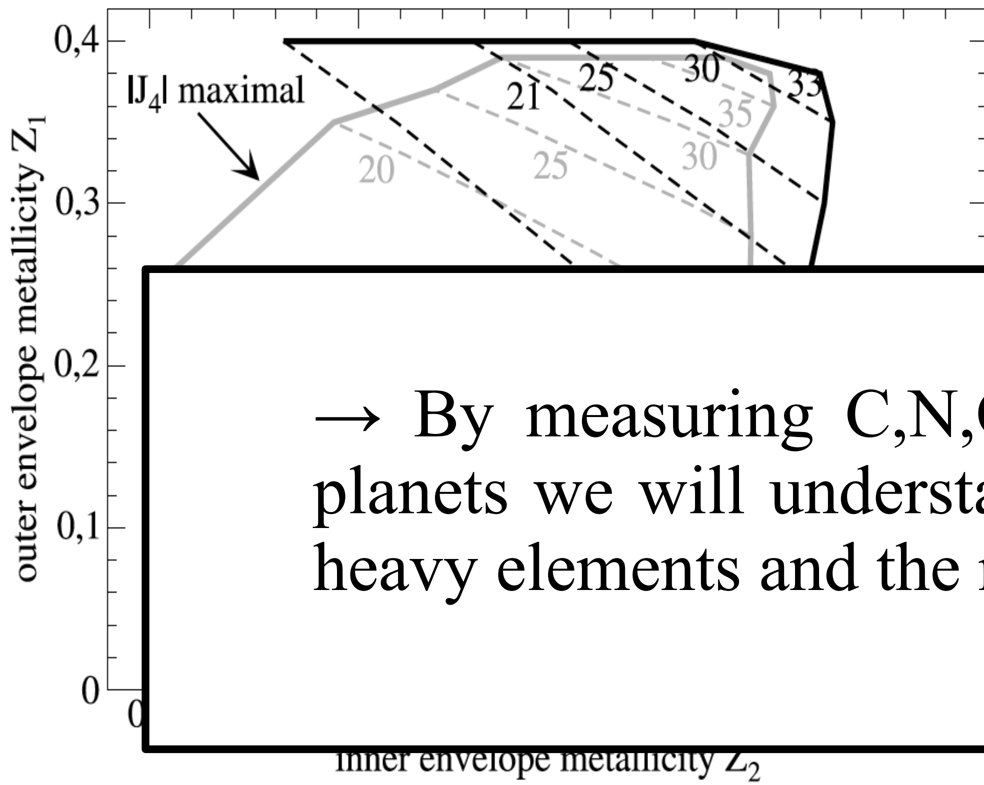
Fortney at al. 2010



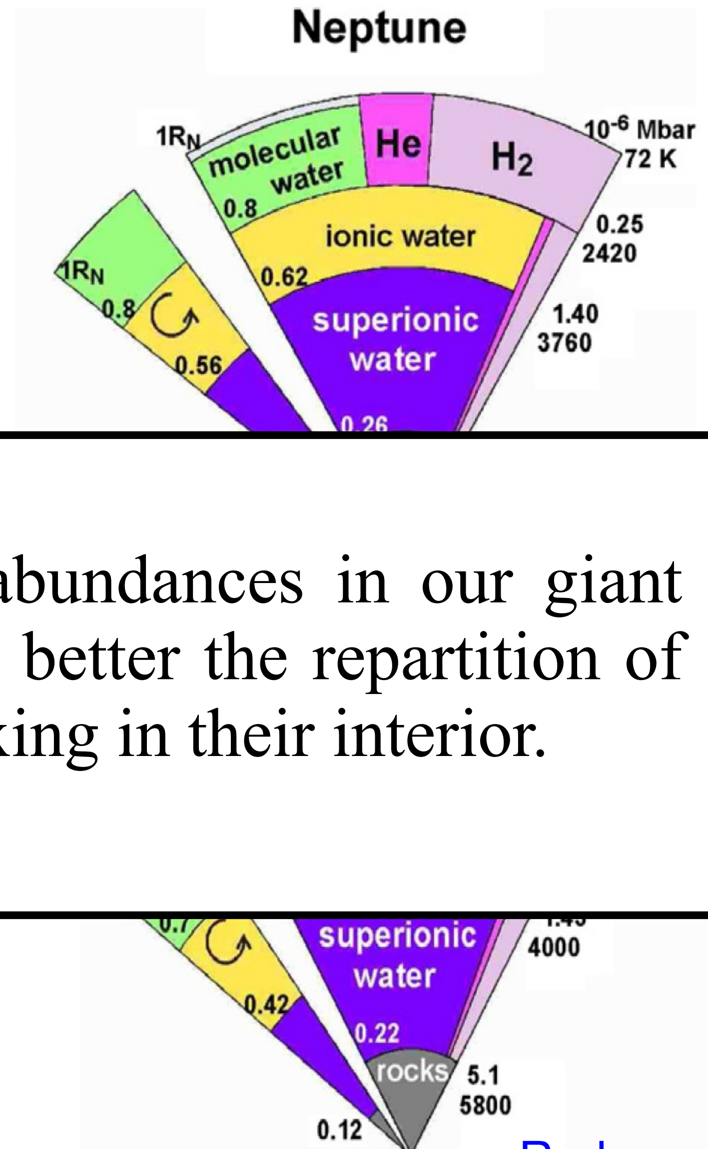
Redmer et al. 2010

→ No solutions for a three homogeneous layers model for Uranus and Neptune.

C,N,O as a proxy for the heavy elements contents of the envelope



Fortney at al. 2010

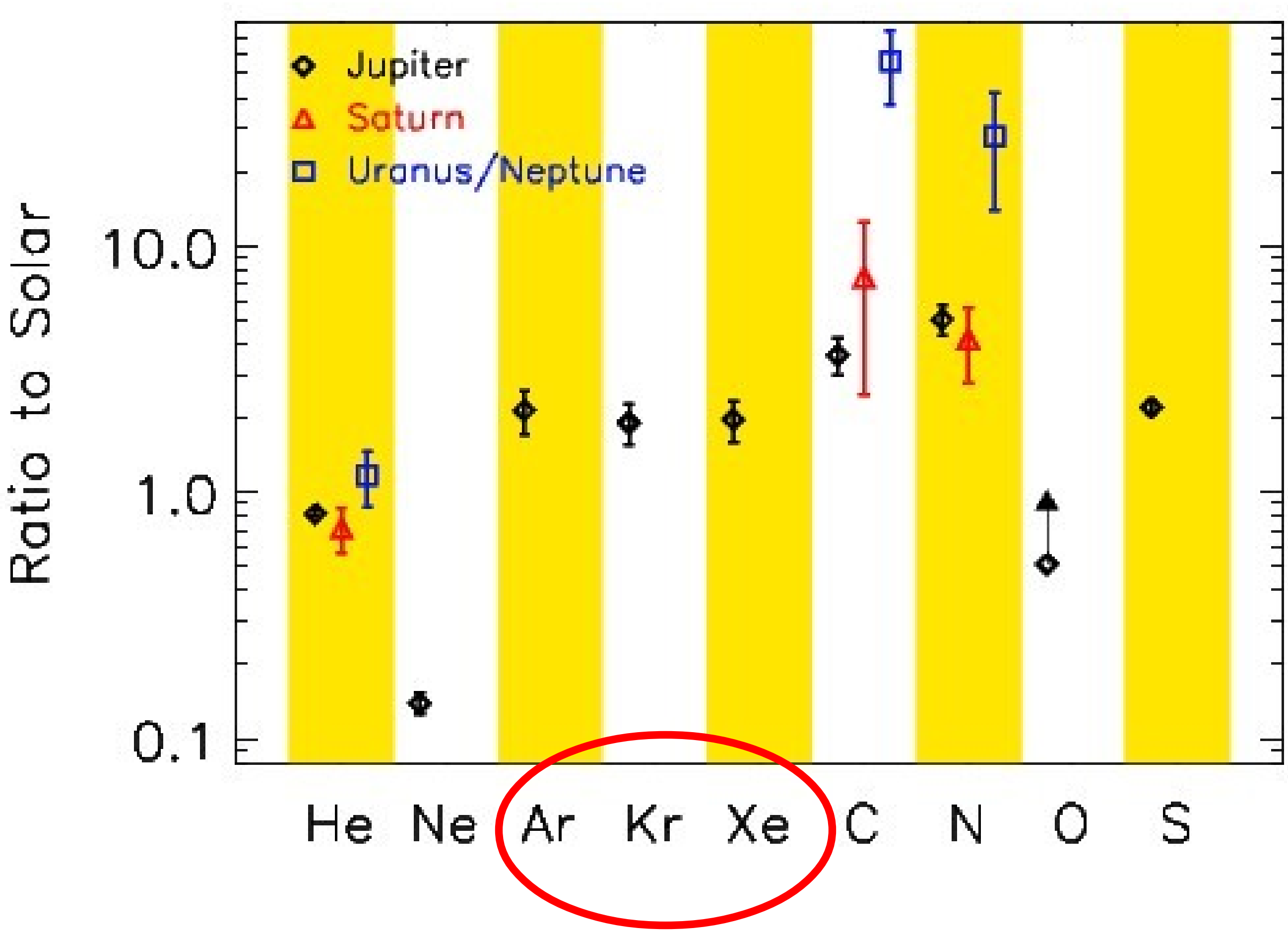


→ By measuring C,N,O abundances in our giant planets we will understand better the repartition of heavy elements and the mixing in their interior.

Redmer et al. 2010

→ No solutions for a three homogeneous layers model for Uranus and Neptune.

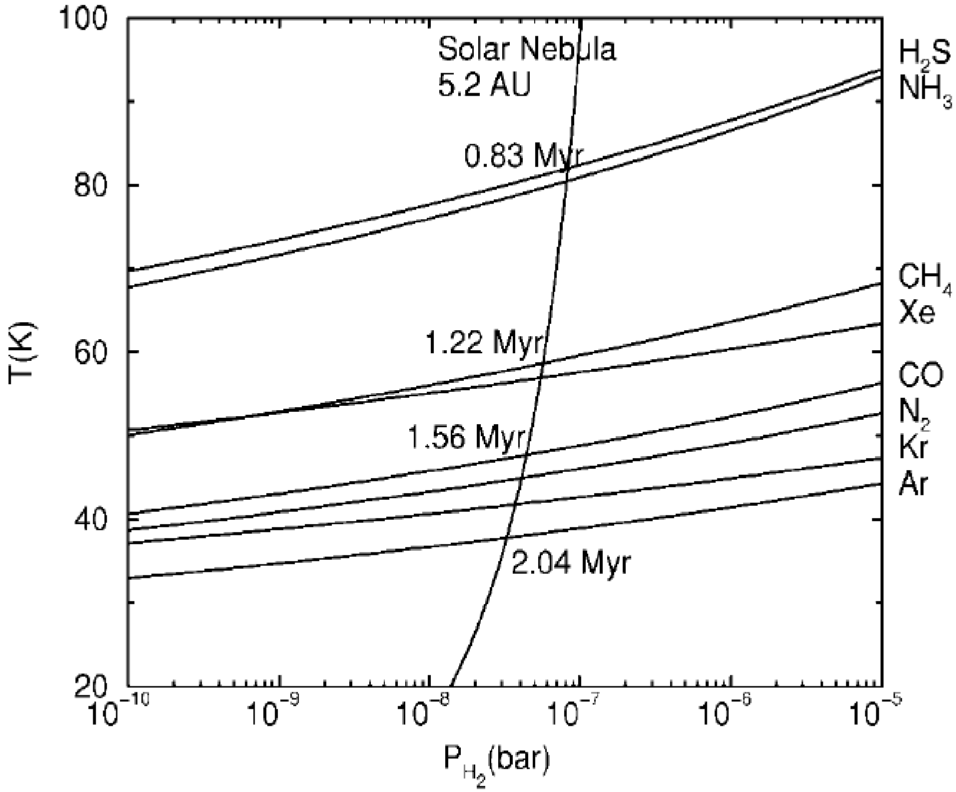
Noble gases as a proxy for the accretion mechanism in the solar system

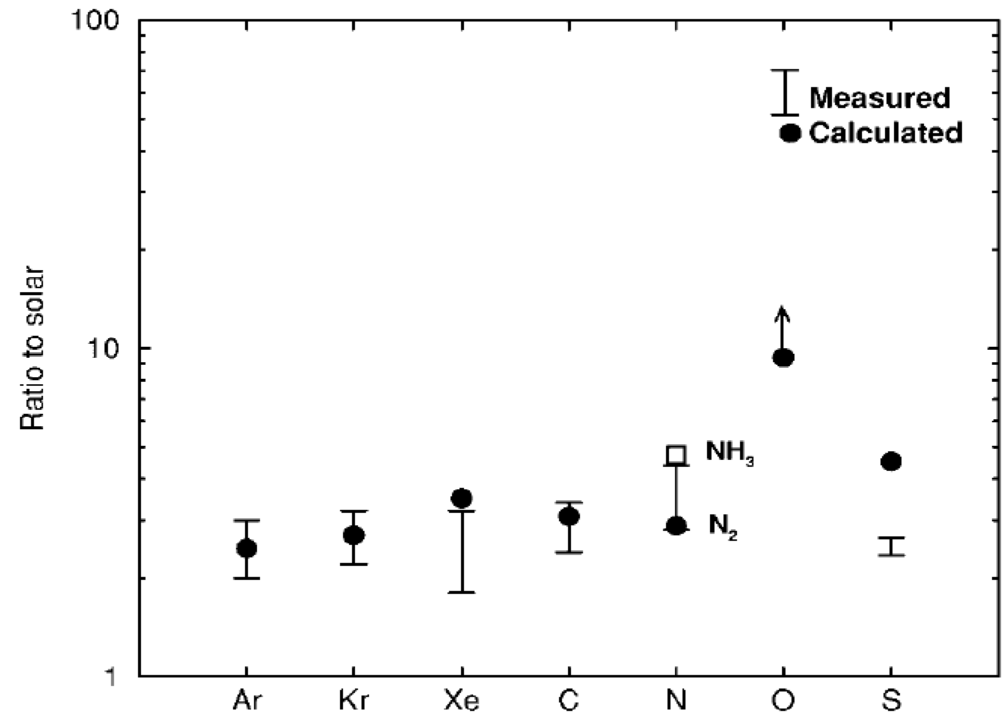


See Atreya et al. 2003, Gautier et al. 1995
Solar reference: Grevesse & Sauval 2002

Noble gases enrichment : three possible scenarios

- Noble gases are trapped in clathrates (Gautier 2001) – cold disk



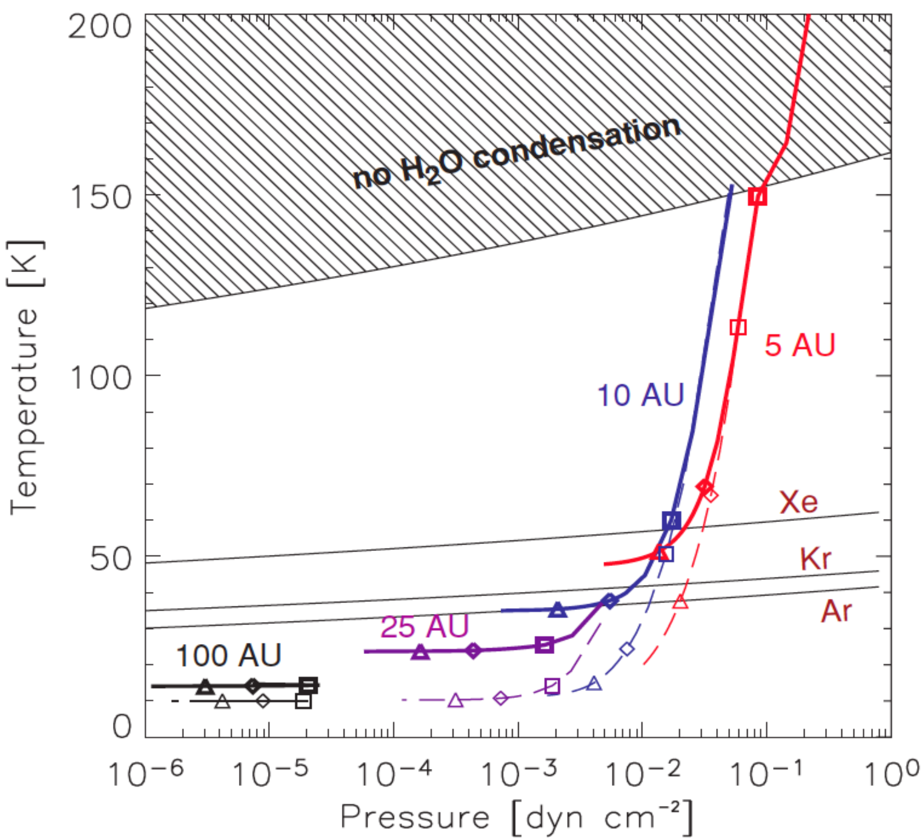


→ Works but need a very efficient clathration process in order to be coherent with the inferred heavy element mass in Jupiter.

Noble gases enrichment : three possible scenarios

• Noble gases are trapped in clathrates (Gautier 2001) – cold disk

• Noble gases are concentrated in the inner disk by grain migration and later accreted as gas (Guillot & Hueso 2004) – warm disk



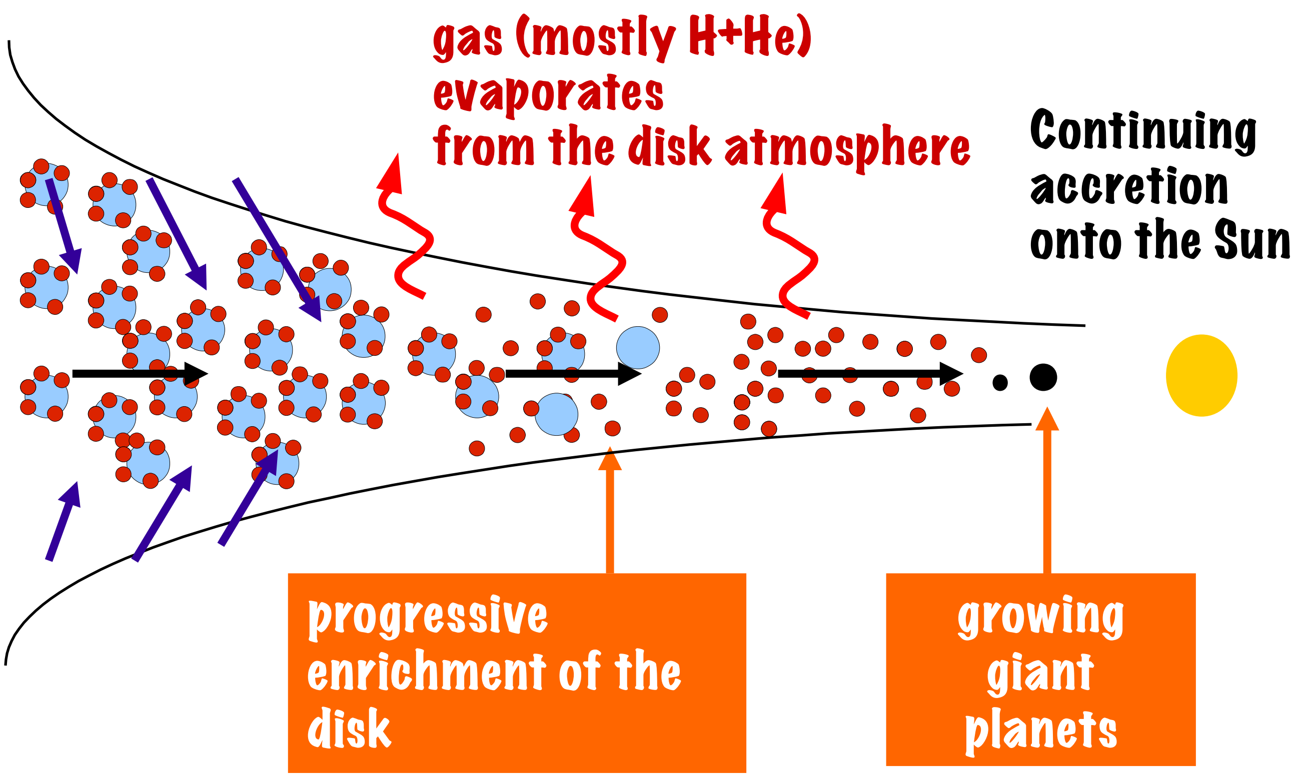
Irradiation makes the disk too hot to condense the noble gases at 5AU.

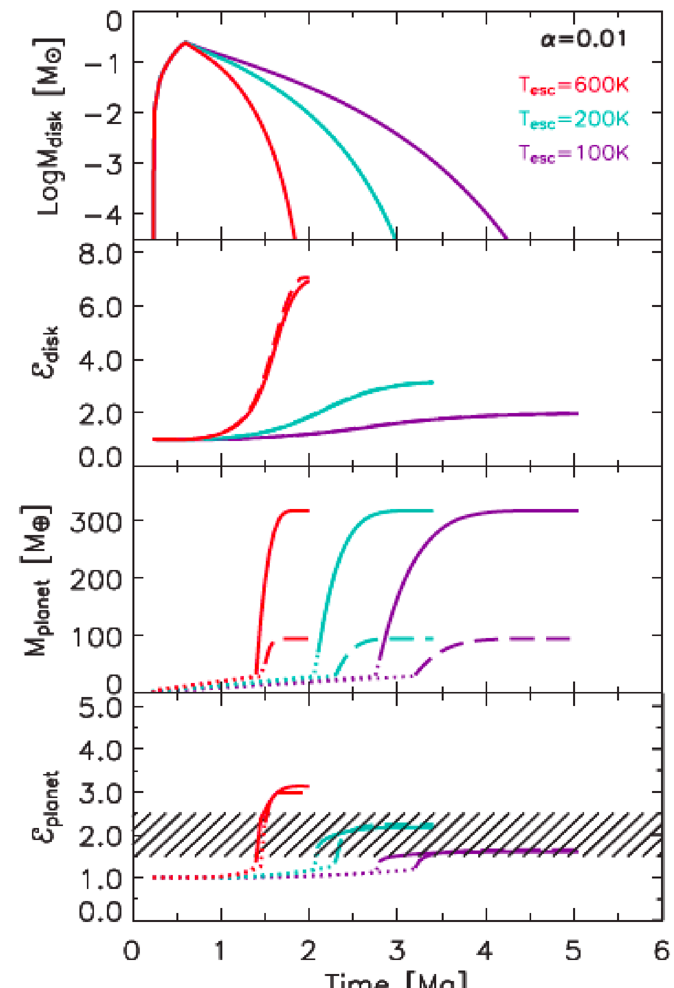
But further away it is cold enough and they should condense in grains.

Noble gases enrichment : three possible scenarios

• Noble gases are trapped in clathrates (Gautier 2001) – cold disk

• Noble gases are concentrated in the inner disk by grain migration and later accreted as gas (Guillot & Hueso 2004) –



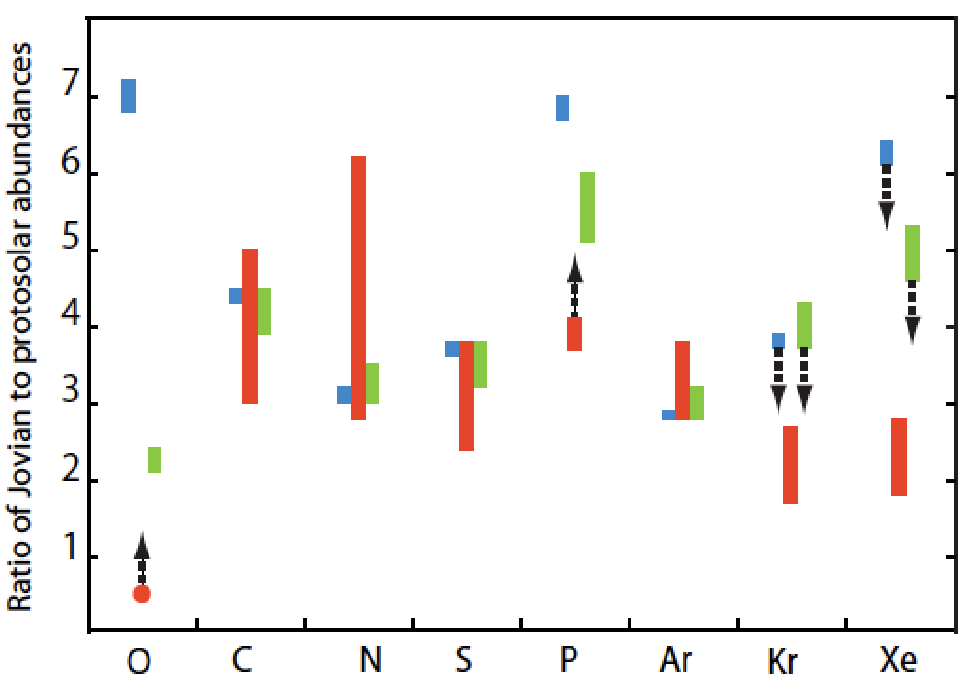


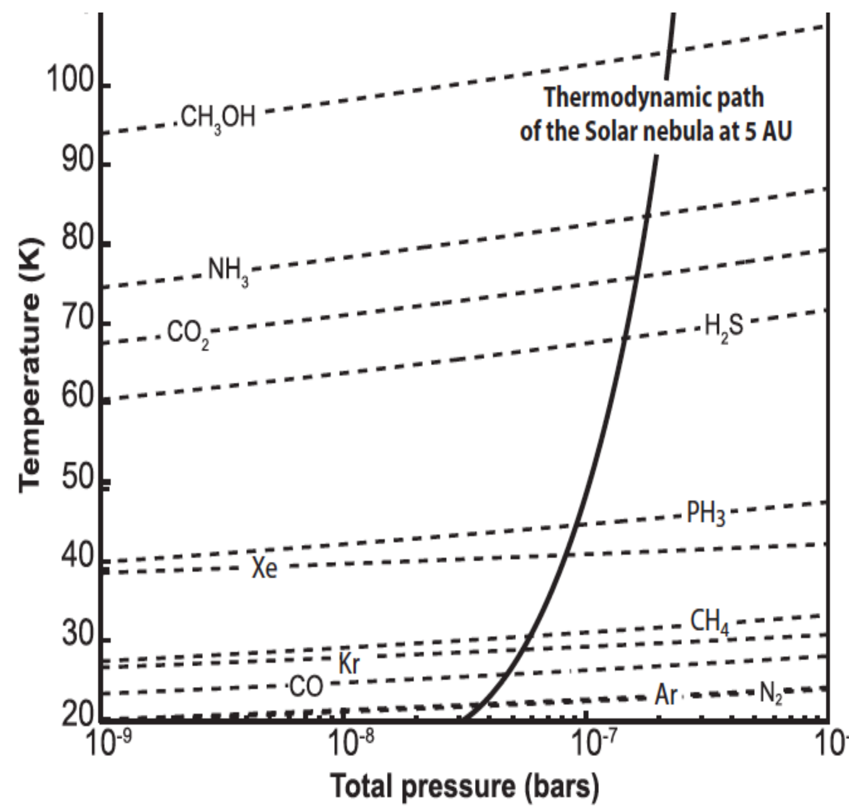
Noble gases enrichment : three possible scenarios

• Noble gases are trapped in clathrates (Gautier 2001) – cold disk

• Noble gases are concentrated in the inner disk by grain migration and later accreted as gas (Guillot & Hueso 2004) – warm disk

• Noble gases are accreted as solids in a very cold disk depleted in water. (Mousis 2012) – very cold disk



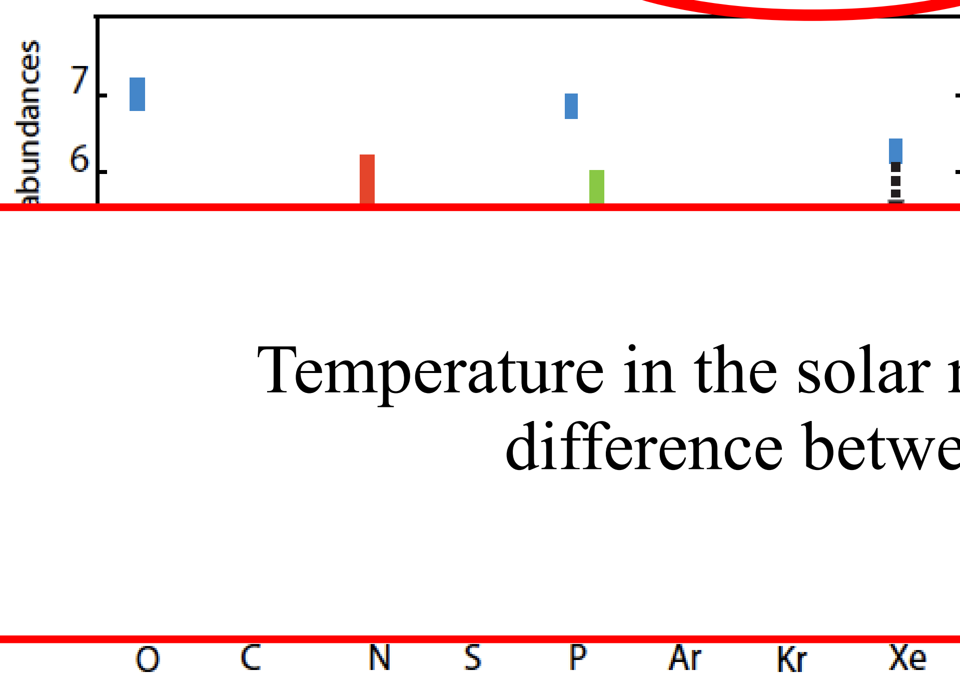


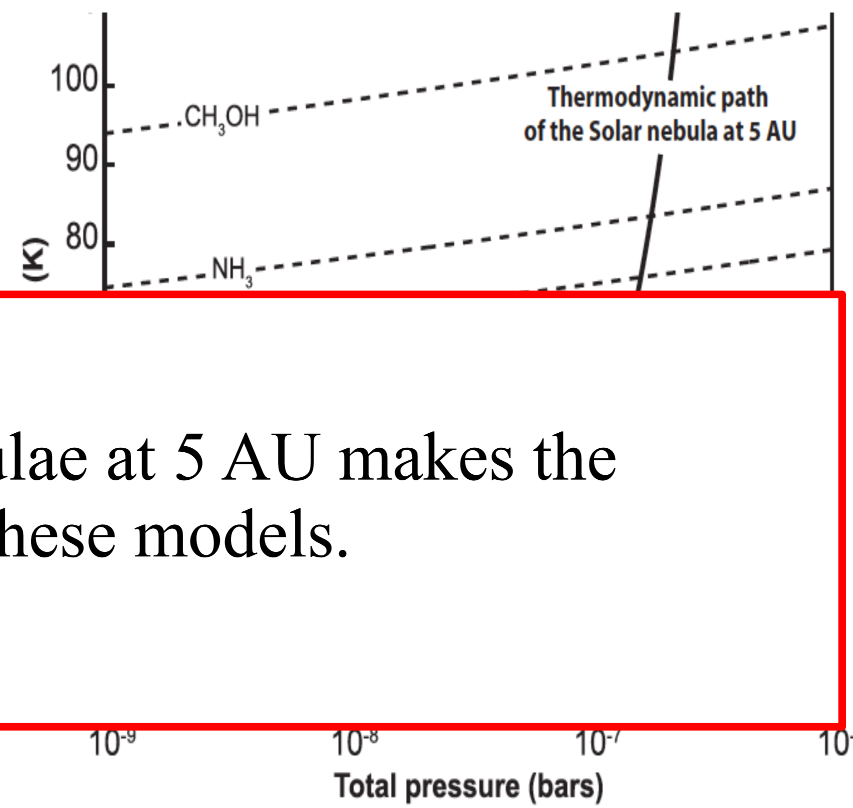
Noble gases enrichment : three possible scenarios

• Noble gases are trapped in clathrates (Gautier 2001) – cold disk

• Noble gases are concentrated in the inner disk by grain migration and later accreted as gas (Guillot & Hueso 2004) – warm disk

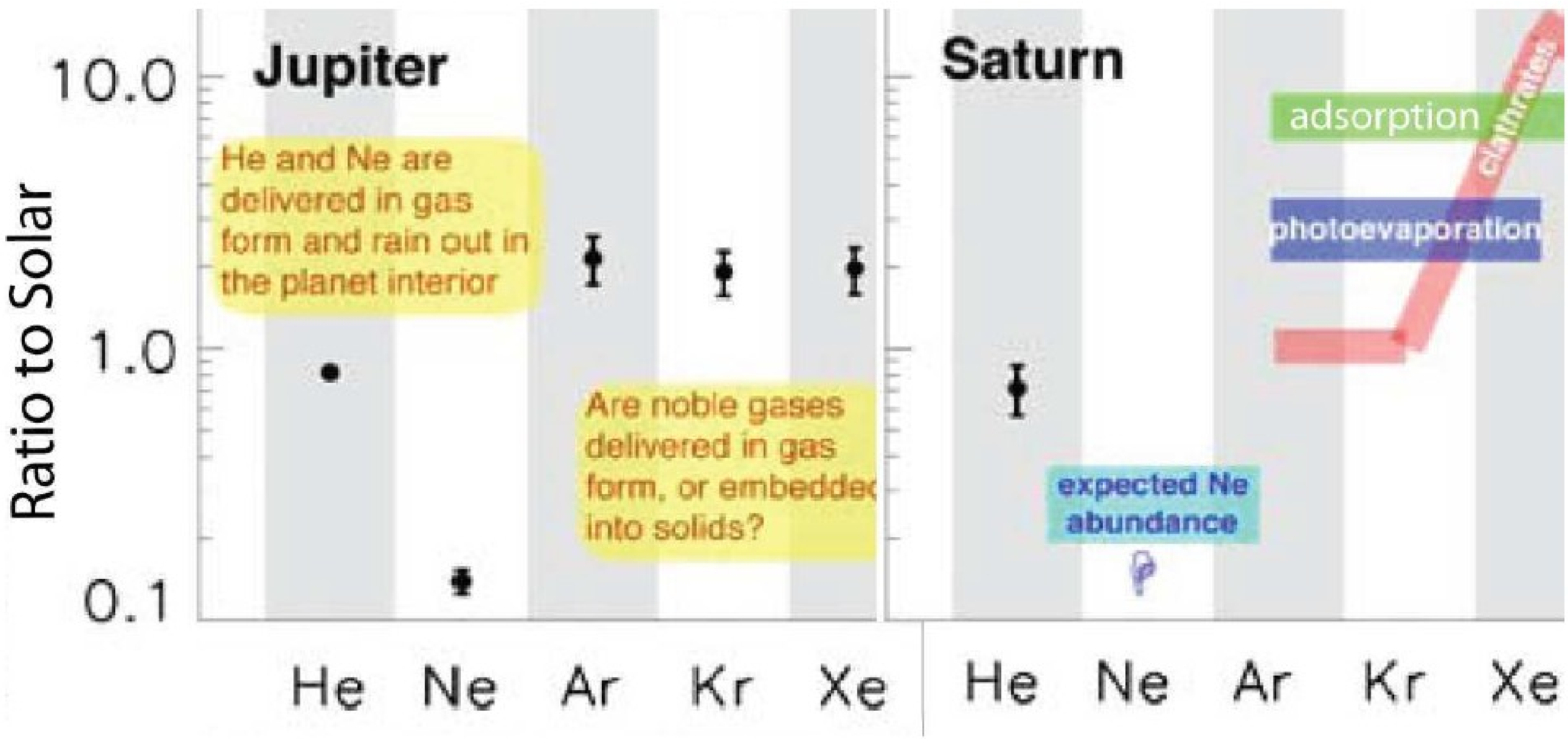
• Noble gases are accreted as solids in a very cold disk depleted in water. (Mousis 2012) – very cold disk





Temperature in the solar nebulae at 5 AU makes the difference between these models.

Noble gases enrichment : three possible scenarios



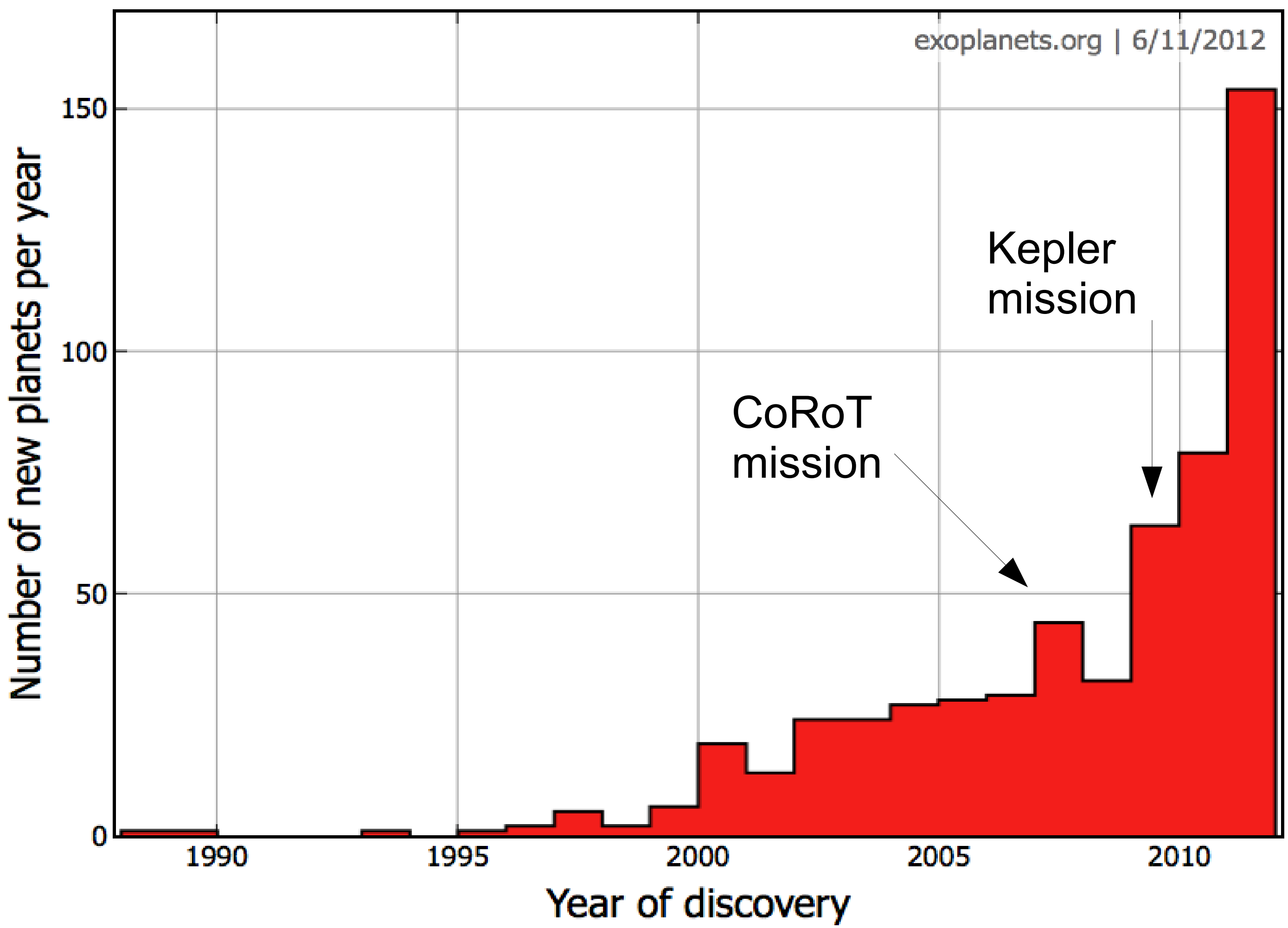
→ In-situ measurements on Saturn will allow us to differentiate between the scenarios and learn more about the conditions prevailing in the solar nebulae.

A lot of other interesting measurements

Species	Consequence
He	Determine extent of helium sedimentation in Saturn's interior. Crucial for accurate understanding of the thermal evolutions of Saturn and Jupiter
Ne	Test prediction of Ne capture in He droplets. Refine H–He phase separation diagram
CH_4	Fine determination crucial to understand the formation of the planet
NH_3 NH_4SH	Key to decide between models of planetesimal delivery and planet formation. Important for Saturn's meteorology
H_2S NH_4SH	Key for planetesimal delivery, with possibility that the abundance is linked to that of rocks deep inside. Important for Saturn's meteorology
H_2O	(by radiometry); Key to understand the planet's structure, formation, and meteorology
Ar, Kr, Xe	Key to decide between models of planetesimal delivery and planet formation. Link with the compositions of the Sun and protosolar disk
CO, PH_3, AsH_3, GeH_4	Disequilibrium species are important to understand convection in Saturn's deep atmosphere. Help to further test planetesimal delivery models
D/H	Test models that predict it should be similar to Jupiter and to the protosolar value
$^{12}C/^{13}C$	Test models that predict value similar to Earth
$^{14}N/^{15}N$	Important to understand whether N was delivered as N_2 or as NH_3. Test models of planetesimals delivery
$^{20}Ne/^{22}Ne$	Origin of gas, Test evaporation processes in the early solar system
$^{36}Ar/^{38}Ar$ Kr, Xe isotopes	Origin of gas, Test evaporation processes of these gases in planetesimals

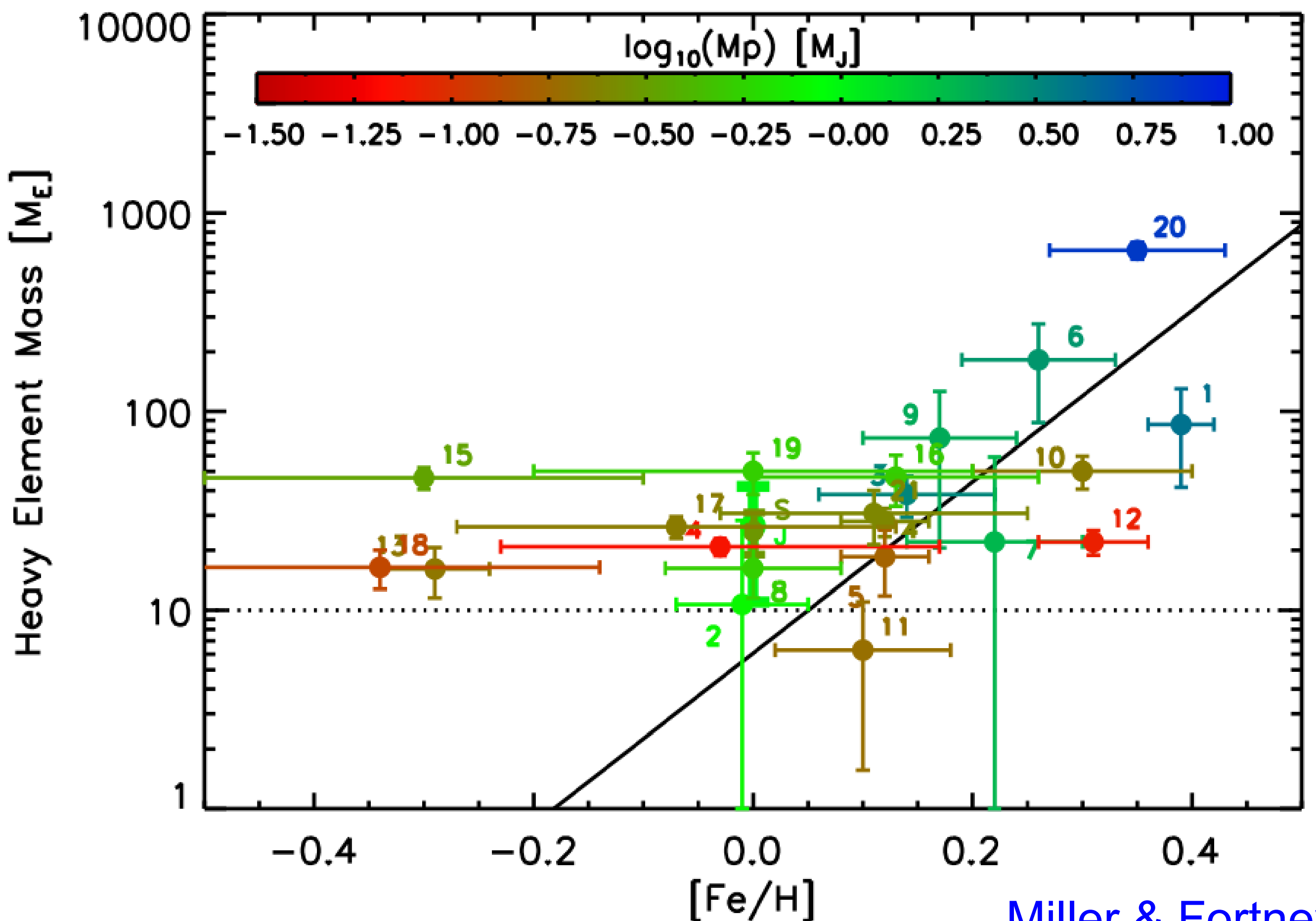
Marty et al. 2009

What will we learn before the next probe in giant planets ?



→ With 779 confirmed planets and thousands of candidates, we can now study planets as a class of objects.

What will we learn before the next probe in giant planets ?



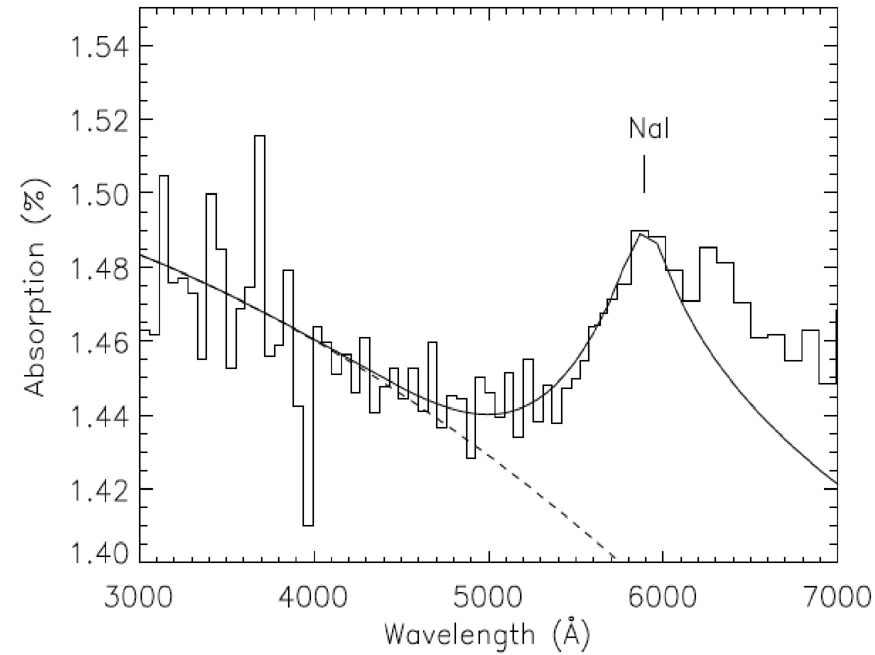
Miller & Fortney 2011

→ Statistical study of gas giant exoplanets will enlighten us about the general mechanism to form planets.

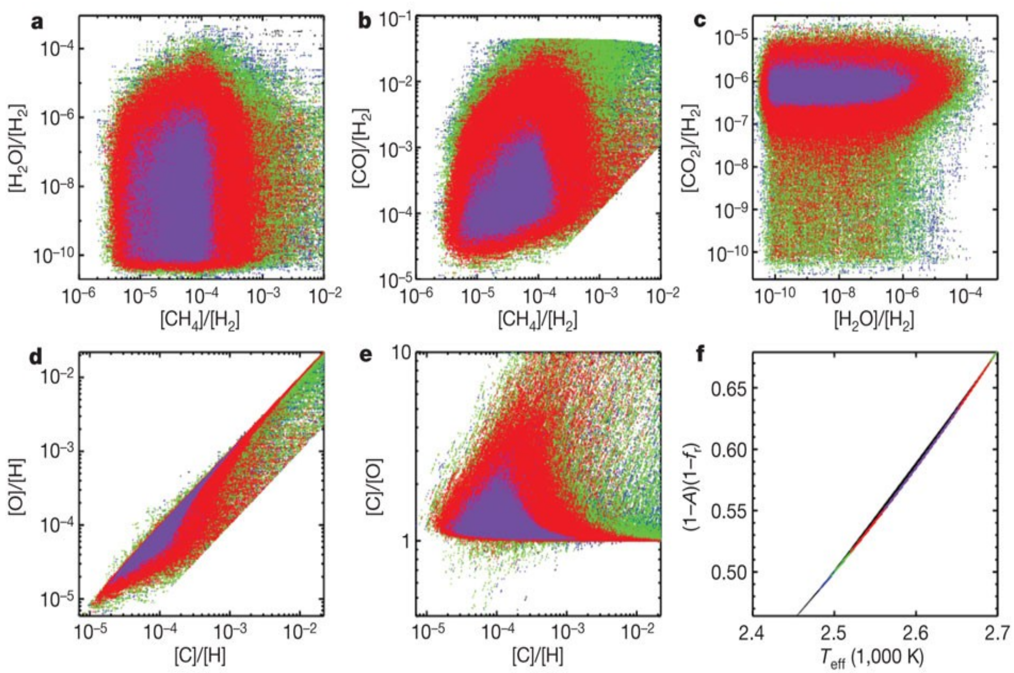
What will we learn before the next probe in giant planets ?

In hot-Jupiters we can see molecules that are hidden in our giant planets :

Water, methane, carbon monoxide, sodium, potassium, titanium and vanadium oxide, atomic hydrogen ...



Lecavelier des Etangs et al. 2008

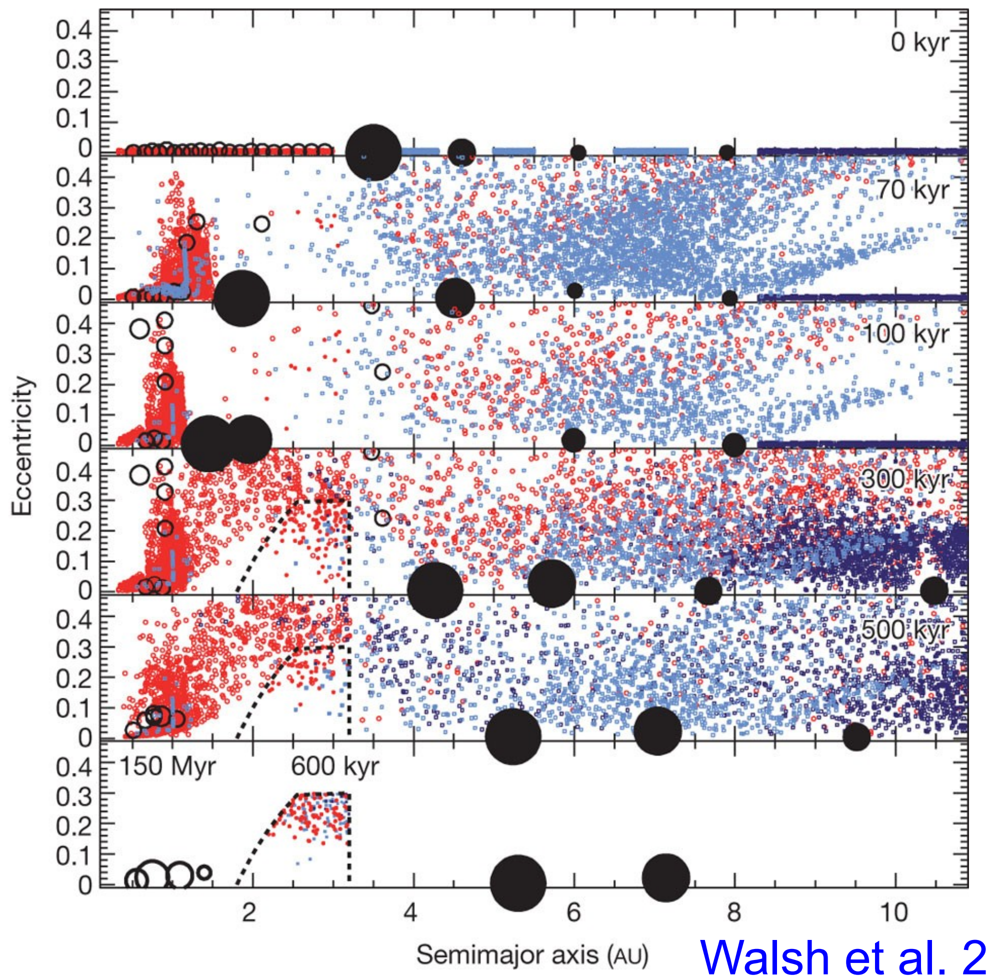


Madhusudhan at al. 2011

As the measurements become more precise, we will get clues on the formation of giant planets in general.

All giant planets should eventually be probed !

Planetary formation was a stochastic process and created planets with very unique features.



Walsh et al. 2011

→ It is only by probing our own giant planets that we will discover the specific history of our solar system.